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BUILDING RAILWAYS ACROSS PEAT BOGS OR SWAMPS.

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In some parts of Canada large areas of peat bogs or swamps are met with; and when locating lines for railways, the engineer frequently has to carry the line over these, or avoid them by taking a line objectionable in other ways, and in some cases it may be impossible to avoid them altogether. The following observations may be helpful to some engineer who may have to handle such work without having had previous experience in that way.

In building railways over such ground, the method of construction will, in most cases, either be to form a raft of some kind on which the weight of the track and trains will be, as it were, floated over the yielding mass beneath, or to fill in hard material until a solid bank is formed from the bottom of the swamp upwards. The use of timber trestles, being intended usually as only a temporary expedient, need not be considered here. If the swamp is at all deep the plan of filling in is both expensive and uncertain, so that the first method should be adopted whenever practicable, which will be the case almost always when the grade line can be kept down close to the surface of the swamp.

When the swamp can be drained to a depth of from two to five feet, the cheapest and most convenient plan will be to cut side ditches on both sides of the road bed, with such off take drains as may be needed to take the water out of the side ditches, and to use the material taken out of the side ditches to make a light embankment. The body of partially dried peat between the side ditches is then sufficient to carry the light embankment with the track and trains. In this way railways have been carried over swamps so deep and soft that one man could push a pole into the muck for twenty feet or more, and pull it out again. If the depth of peat is so small that the ditches reach the firm stratum beneath, the raft becomes a more or less yielding cushion under the track.

If drainage can be got, the side ditches should not be less than three feet deep, and on account of the difficulty of working, it is not advisable to make them deeper than five feet. Unless the quantity of water to be carried off be very great, the width need not exceed six to eight feet. The off-take ditches should be made large enough to carry off the water, but it should be borne in mind that after the surface of the swamp is once dried, there will not be so much water to be carried off afterwards; and if the ditches are made wider than necessary, they will be more liable to choke than when they are so narrow that the water will have depth and force enough to scour them out.

Except where the grade line cannot be made low on account of the shape of the firm ground adjoining the swamp, a high bank is not advisable, because the additional weight only tends to sink it deeper; and,

as banks made of muck tend to become wider as they settle, and should be covered on the sides as well as on the top with sand or gravel as soon as possible after the track is laid, to keep them from taking fire and burning away, the muck banks should not be made more than twelve feet wide on top for a standard gauge railway, so that the quantity got from side ditches of the size mentioned above will be ample to form the roadbed. It is usual to make the sides of the ditches vertical or nearly so, and they will stand in this way for many years without falling in, but it would be as well, if only for the sake of appearance, to have them sloped. It will prove true economy in the long run to be liberal in the matter of off-take ditches. The light moss from the top of the ditches and roots and sticks found among the muck are frequently wasted, but might as well be put into the banks, for except that they make the bank more compressible at first, they do no harm, and the work will look neater than if they are left in heaps outside; but if not put into the bank, they should be burned for the sake of appearance.

The berms should not be left very wide, one and a half times the depth of the side ditch plus five feet, measured from the slope stake to the inside edge of the bottom of the ditch, would be a good rule in most cases, unless allowance is being made for a second track, in which case the width of the roadbed should be added on one side to the above. The objection to wide berms is that the weight of the bank causes the inner side of the berm to sink lower than the outside, thus forming a depression along the foot of the slope in which water collects, forming unsightly pools and softening the banks.

As the surfaces of such swamps are either level or slope gently, a surface line will always give easy grades; and the grade line should as nearly as possible be a line parallel to the surface of the swamp, thus making the side ditches of uniform size.

The swamp will settle as it is drained, and the bank as it becomes consolidated, but in ordinary cases no attempt should be made to raise them up to the original profile grades, the cost will be greater than any gain, and the additional weight may even cause the bank to break through the crust.

When the swamp is too wet to allow a bank to be made in this way, and drainage cannot be got, and the grade line can be kept close to the ground, a raft may be made of logs or brush, or both, with enough peat on top to hold the track and keep the ballast from sifting through. In this case it would be better to take the peat or muck from some distance outside the ends of the logs, as by cutting the skin of the swamp close to the road its bearing power would be diminished. One tier of logs should be laid lengthways of the road, to help to diminish the undulations of the track under trains. The cross logs should be as long as can be conveniently got and handled, so as to distribute the weight over as wide an area as possible; but there is no gain in putting down more than two or three tiers of logs, as the weight will tend to sink the raft down, and the object is to carry the track over the crust of the swamp without breaking through. But when the crust of a soft swamp has been broken, and the hole has to be filled up, if timber is plentiful and convenient, it may be used simply as filling, and will have a certain advantage from its not being softened and dissipated by the water as earth or sand would be, and in deep bogs may form a submerged raft capable of carrying the required load.

Sawdust has been used with success for filling low trestles on the Wabigoon section of the Western division of the Canadian Pacific Railway, both in cases where the banks had broken through the surface and where great quantities of gravel had been put in, but without bringing the bank as high as the original surface of the swamp, and also in one case where no other filling had been used and the surface

had not been broken. In this case the trestle was about six hundred feet long and eight feet high, and soundings had been taken to a depth of sixty feet without finding firm bottom. The sawdust was spread out to slopes of three to one to distribute the weight, and track ties twelve feet long were used. Both top and slopes were covered with six inches of gravel. The sawdust settled unequally, and a watchman was kept on for four months, and the track lifted and tamped occasionally, but after that time there was no farther trouble.

The culverts in such swamps should be made of wood, the banks will usually be too low for masonry culverts, and the foundations would be very expensive, pipes either of cast iron or earthenware would be liable to be broken or parted at the joints by the movements of the soil, while wood, if properly put together, would yield to such movements without injury. Being always damp, or at least the lower parts of them, they would last well, especially if made of cedar, and the banks being low, they could easily be replaced at any time.

The chief objection to railways built in this way is the excessive creeping of the rails, caused by the undulations of the track under trains. To remedy this the use of cinder ballast and ties twelve feet long was introduced on the Western division of the Canadian Pacific Railway by Mr. Whyte, the general superintendent, and these have been successful to a considerable degree. The evil might be still further lessened by the use of stiffer rails.

When the bog is too soft to carry any embankment, however light, or the grade line cannot be kept near the surface, there will usually be no other way than to fill in firm material until a solid bank is formed from the bottom up. In making estimates for this, not only should the bottom of the fill be assumed to be at the bottom of the soft material instead of the surface, but large additions should be made to the quantities so calculated, because the soft material, being displaced by the filling, will slip out sideways and carry portions of the latter with it. In many cases the division between the bog and the underlying material will not be distinct, but the one will merge gradually into the other, and in such cases the quantities of filling required will be correspondingly uncertain. The worst cases are usually where the soft muck is underlaid by soft and slippery clay. It is a common practice to get the track over such places by using timber trestles, leaving the permanent work to be done later; but when this is done, careful soundings should be taken and the method of doing the permanent work and its probable cost fully considered. This might not seldom result in the adoption of some other line, or a change of grades, which though more costly in the first place would be very much cheaper in the long run, as well as safer. It should be kept in mind that the filling of these trestles is often left until the traffic over the road is large, then not only will the work of filling be delayed by the traffic, but the latter will also be hindered or possibly interrupted for days together by the accidents which are almost sure to happen in the course of filling high trestles over soft ground, in spite of all the care and precautions that can be taken, and in addition to these delays there will be the cost of maintaining the trestles in a passable condition, perhaps even of rebuilding them. If all these things were taken into account, it would often be found to be really cheaper to take heavy rock work than to make high fills through these bogs; this will be understood when it is borne in mind that rock increases in bulk when broken up, that it will not take flatter slopes for being wet, as is the case with earth filling, and will not be so readily carried away by the movement of the soft material as would sand or gravel. Besides, in many cases a rock embankment would avoid the need for a culvert.

But when it has been decided to cross any such soft ground at a high level by means of trestle work, to be filled in afterwards, the per-

manent structure, if any required for the passage of water, should be decided on, and the work so done as not to interfere with its proper location and construction afterwards. In neglect of this it often happens that the rim of firm ground at the edge of the bog is filled over by the material from cuttings on both sides, making the foundations of the permanent structure a matter of great difficulty and expense. Such bogs are often bounded by rocky ridges; and when these are so shaped that tunnels for the passage of the water can be driven through them without being too long, they may be cheaper as well as more secure than masonry culverts; the comparison will depend chiefly on the respective lengths of the culvert and the tunnel and the size of the opening required. But this question should be decided before the site of the proposed tunnel is covered over, the tunnel should be located, test pits dug or borings made, and the results left on record, otherwise it may be difficult afterwards to ascertain whether the rock is suitable for a tunnel or not. If a stream tunnel is not possible or suitable, the culvert will, of course, if at all possible, be placed on firm ground, beyond any danger of movement; if this is not possible, it would perhaps be better to build it strongly of wood, making it so large that a pipe or brick culvert large enough to carry the water can be built inside it after the bank has done settling. Sometimes a platform of logs is used under the fill; but if the fill is at all heavy, this is not of any use, as it will be broken up or sunk, and in any case will count only as so much filling, when it will seldom be as cheap as gravel, and will make it more difficult to keep the trestle in shape.

If clean, coarse gravel can be got, it is preferable for filling to the fine soft sand that is usually found near these swamps.

By keeping the filling spread out to the full width of the slopes from the start, it will settle more evenly and be less liable to sudden slips, which might distort or wreck the trestle; this spreading out can often be done cheaply by teams and scrapers. When the rock or firm ground at the ends of the fill slopes steeply, if the filling is ploughed off uniformly over the length of the trestle, it is apt to slide towards the middle of the trestle, and so crowd the bents; this may be prevented to some extent by filling from the middle towards both ends. In such ways, by careful watching and distribution of the filling, much may be done to preserve the trestle in a passable condition, but in all bad cases, a bridge crew should be kept on the work, and plenty of material for repairs should be kept on the ground. It will be an advantage to have as many as possible of the men working at the fill boarded close by, and arrangements should be made so that additional men can be got and accommodated, and ample material and tools procured at short notice in case of emergency.

The objections to undertaking heavy fills across soft bogs, and the precautions that should be taken when such work has to be done, noted above, apply even more strongly to the case of ponds or lakes with soft and muddy bottoms, which may be considered as bogs with their surfaces covered to a greater or less depth with water. The most valuable assistance the engineer can have will be a few good men who have had some experience on similar work.